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(54) Title of Invention

Control of drilling courses in the drilling of bore holes

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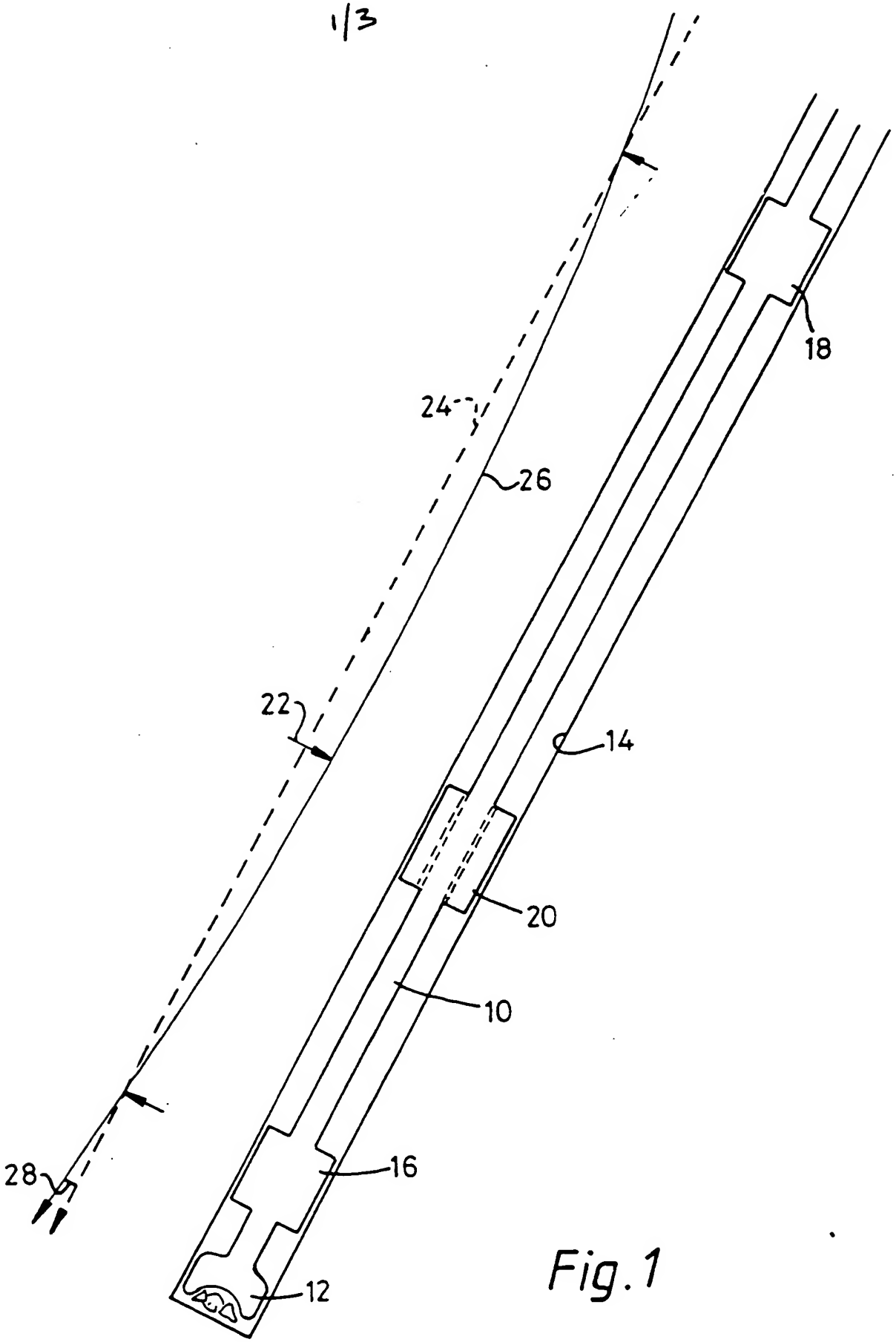

Fig. 1

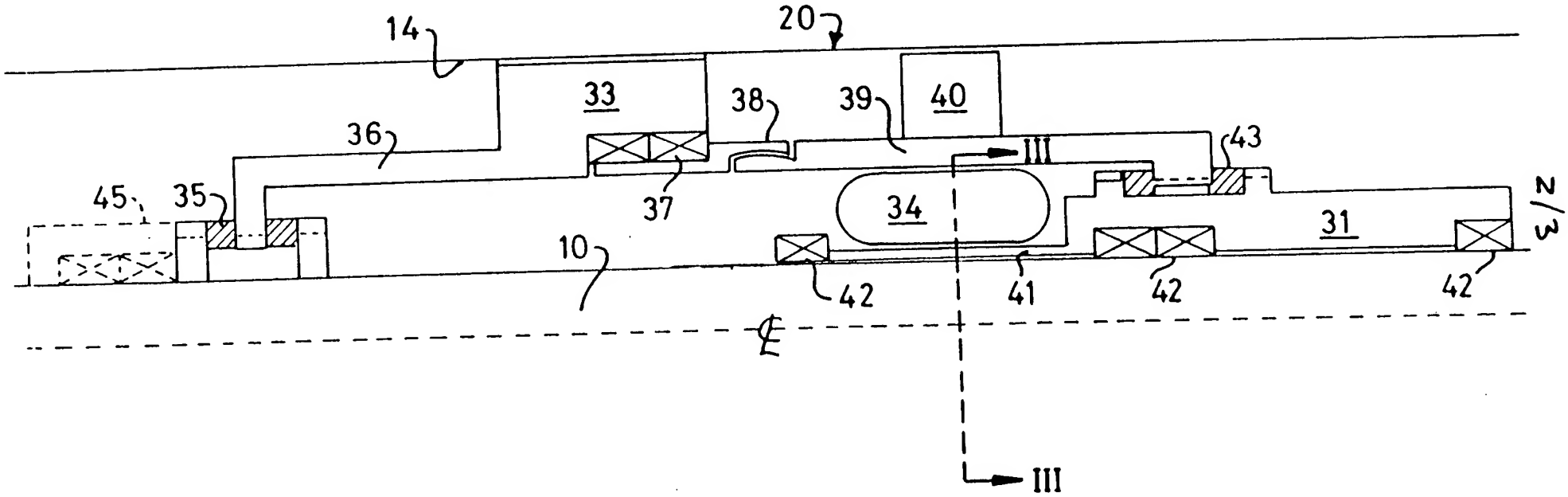

Fig.2

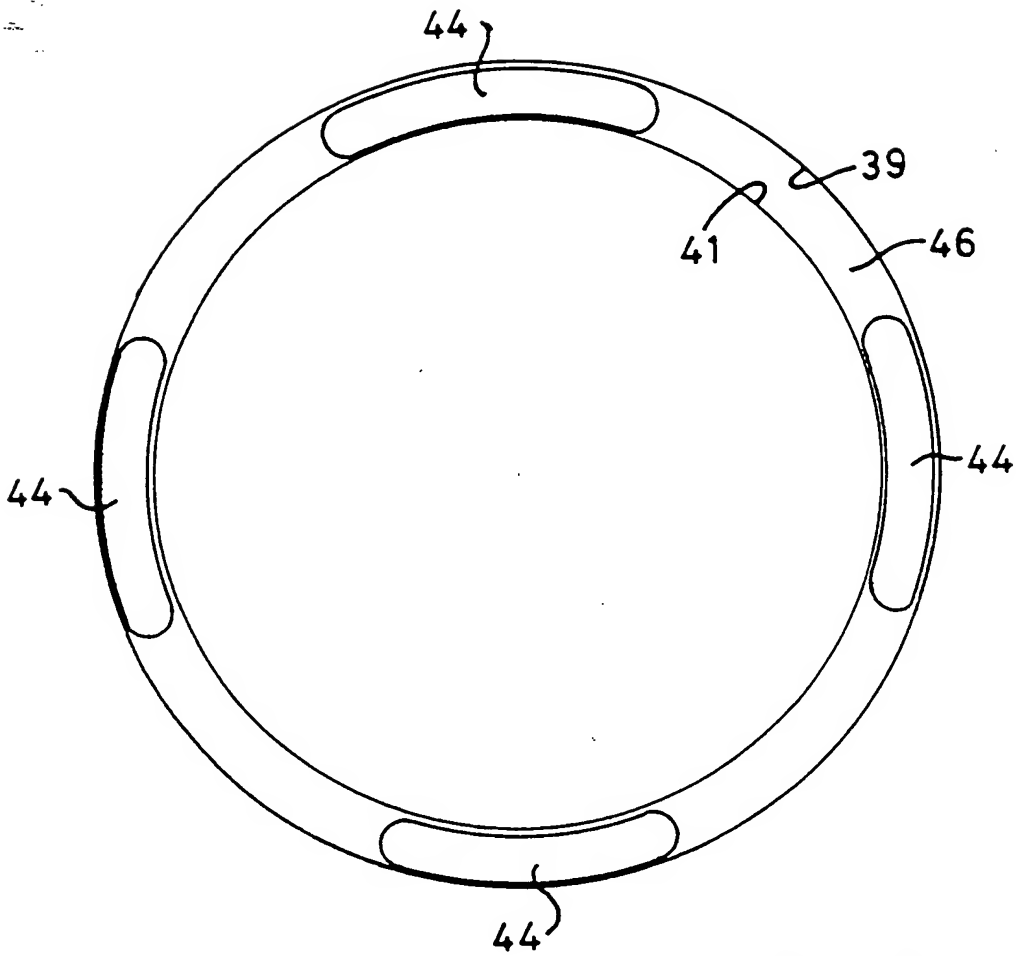

Fig.3

Control of Drilling Courses in the Drilling of Bore Holes.

Field of the invention.

This invention relates to the control of drilling courses in the directional drilling of bore holes, for example in the fields of oil extraction, oil exploration, mineral exploration and geothermal energy extraction. The invention is concerned with apparatus for use in rotary drilling, rather than turbine drilling which uses down hole motors.

Background to the invention.

Currently, course control with conventional rotary drilling is particularly difficult and time consuming, other than for purely vertical bore holes. However, rotary drilling has the potential to be very attractive in directional drilling since it is economical. In fact, many drillers revert to conventional rotary drilling when drilling the inclined tangent section of directionally drilled bore holes, despite the associated difficulties. A typical assembly of drill string components near the bottom of a bore hole may consist of a drill bit, drill collars and stabilisers, this being known as a bottom hole assembly. A drill collar is a heavy drill pipe whose

function it is to transmit the drilling torque and axial thrust to the drill bit as well as to provide weight and to provide a connection to the other drill string components above. A stabiliser is a device which is approximately the same diameter as the bore hole wall and acts to centralise the drill collar in its vicinity. Sections of drill collar, stabilisers and the drill bit are joined by screwed connectors. An aim of the invention is the attainment and/or maintenance of desired drilling courses by the use of means which provide a controlled deformation or displacement to the drill string.

Summary of the invention.

According to one aspect of the invention apparatus for deflecting a rotatable drill collar used in rotary drilling comprises actuating means which do not rotate with the collar and which are operative to apply a controlled lateral force or displacement to the drill collar in order to deflect the latter to control the direction of drilling, the actuating means and the control thereof being down hole. In use, the actuating means are located in the bore hole, the wall of which provides a reaction to the deflecting force applied to the drill collar.

The actuating means preferably apply controlled forces to the drill collar in each of two orthogonal directions, so that a deflection of any magnitude and in any radial direction can be applied by the actuating means to the drill collar. This gives complete control over the direction of drilling followed by a drilling bit attached to the lower extremity of the drill collar.

According to another aspect of the invention drilling

apparatus comprises a rotatable drill collar, a drill bit carried by the end of the drill collar, two spaced stabilisers which act to locate the drill collar within a bore hole being drilled and down hole control means for controlling the drilling course, the control means comprising sensing means for sensing the actual drilling course, information storage means for storing a predetermined required drilling course, comparison means for comparing the sensed course with the required course and for delivering an error signal in dependence upon the comparison, and actuating means which do not rotate with the collar and which apply a controlled lateral force or displacement to the drill collar in order to deflect the latter between the spaced stabilisers to vary the drilling course in dependence upon said error signal.

The sensing means preferably sense direction and inclination of the bore hole course relative to the earths magnetic and gravitational fields respectively.

The actuating means preferably include a specially adapted control stabiliser which may be located between said spaced stabilisers which may be conventional stabilisers. One of the spaced stabilisers will be located close to the drilling bit (the "near bit stabiliser") and the other typically 30 to 100ft (9 to 30 metres) behind. The control stabiliser controls the drilling direction by deflecting the drill collar through controlled magnitudes in controlled radial directions, using the two spaced stabilisers as support points. Thus when a change in drilling direction is required, the deflection of the drill collar results in a change in the angle of the drilling bit relative to the current direction of the bore hole. This change in angle results in a change in drilling direction.

The information storage means may be provided with

information which relates to the desired direction and inclination of the bore hole course, and also to the maximum desired curvature of the bore hole during the transition from the initial bore hole course to the desired bore hole course. Information can be supplied to the information storage means either when the latter is on the surface prior to drilling or when in situ during the drilling operation when a course change may be required.

When on the surface, an electrical contact will be made with the information storage means and the required data transmitted in digital form. When in situ, information can be transmitted to the information storage means in the following way. Rotation of the drill collar in the vicinity of the control stabiliser can readily be detected since certain parts of the control stabiliser are normally stationary. In its simplest form this could be counting pressure pulses from the reciprocating hydraulic pump. Thus, when it is required to supply information, a timed, coded sequence of drill string rotations and stop rotations, or reverse rotations, is initiated from the surface. This code can be recognised and the information storage means can be triggered into a receive information mode. A following timed sequence of drill string rotations, stop rotations, or reverse rotations, provides the required information of direction, inclination and curvature which is recognised and stored by the information storage means. Alternatively, the coded rotation of the drill collar could be sensed from the voltage produced by an electrical generator driven by rotation of the drill collar.

An alternative method of supplying information is to lower down the inside of the drill string a programmer unit by

means of an electrically conductive line. The information storage means may be magnetically or acoustically coupled to the programmer unit and the required information transmitted by a timed sequence of electrical and magnetic or acoustic pulses.

The comparison means and the subsequent generation of signals to drive the actuating means are generated by an algorithm which is stored and processed electronically.

The actuating means deflects the drill collar, in the vicinity of the control stabiliser, in two orthogonal directions by amounts giving the desired magnitude and direction of deflection. The forces to produce these deflections may be provided by flexible tubes or bags which when supplied with hydraulic fluid expand until the required deflections are obtained. A measure of the required deflections are the forces which are applied by the actuators since the essence of the control is to deflect the drill collar between, and relative to, the two conventional stabilisers in the bottom hole assembly. These forces are functions of the hydraulic fluid pressures which are applied to the actuators. Signals resulting from the measurement of these pressures are utilised by the control means, as feedback signals, indicating the attained magnitude and direction of deflection of the drill collar.

The required hydraulic fluid flow and pressures may be generated by a suitable reciprocating pump or pumps which are driven from the rotating drill collar. Control of the hydraulic fluid is exercised by suitable valves which divert the fluid flow in accordance with control signals generated by the comparison means.

The actuating means may include devices other than tubes or bags to apply the controlled lateral force to the drill string. For example, it may be possible to use piston and cylinder devices but the confined space available makes fluid tubes or bags the preferred construction.

Drilling apparatus according to the invention will now be described by way of example with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic view of the bottom hole assembly of drilling apparatus according to the invention,

Figure 2 is a detailed view, on an enlarged scale, of part of Figure 1, and

Figure 3 is a sectional view on the line III III of Figure 2.

Detailed description of the drawings.

Referring to Figure 1, the drilling means comprise a drill collar 10 carrying at its extremity a drill bit 12. The collar 10 is supported and centred in the bore hole 14 by two spaced stabilisers, namely a near bit stabiliser 16 and a far bit stabiliser 18. Between the stabilisers 16 and 18 is located a control stabiliser 20 which applies to the drill collar 10 a controlled lateral force or displacement (indicated by arrow 22) in order to deflect the latter between the spaced supports constituted by the stabilisers 16, 18. Figure 1 illustrates the undeflected drill collar at 24 and the deflected drill collar at 26, the change in drilling direction being indicated by the

angle 28.

Figure 2 shows a half section through the control stabiliser 20, on an enlarged scale. Referring to Figure 2, the control stabiliser 20 has a housing 31 which contains the sensing means, information storage means and comparison means, together with batteries, hydraulic pump, valves and other equipment necessary for the operation of the actuating means. The batteries are for powering the electronic and other equipment associated with the control means. The hydraulic pump is driven from the rotating drill collar by virtue of the relative rotation between the rotating drill collar and the normally stationary housing.

The wall contact assembly 33, which is externally similar to a conventional stabiliser, provides the reaction to the radial force applied to the drill collar by means of the actuator assembly 34. The wall contact assembly may rotate with the drill collar, in which case the forward joint 35, which is connected to the wall contact assembly by a nose casing 36, is arranged to allow angulation about axes normal to and passing through the axis of the drill collar, while preventing rotation about the axis of the drill collar and minimising radial and axial movement. Bearings 37 connect the rotating wall contact assembly with the non-rotating assembly consisting of an angulation coupling 38, an actuator casing 39 and an anti-rotation device 40. The angulation coupling 38 is similar in performance to the forward joint and allows angulation about axes normal to and passing through the axis of the drill collar but prevents relative rotation about the axis of the drill collar and prevents all relative translational movements. The anti-rotation device 40 is

designed to apply radial force to the bore hole wall 14 and provide torsional resistance preventing rotation, while having minimal resistance to axial movement.

The housing 31 is connected rigidly to an actuator bridge member 41. This assembly is located onto the drill collar by means of spaced bearings 42. This assembly is also connected to the actuator casing by means of a rear joint 43 which has the same properties as the forward joint and similar properties to the angulation coupling.

The actuator assembly 34 consists of four individual actuators 44. These actuators 44 lie within the annular space 46 between the actuator casing 39 and the actuator bridge member 41 and each actuator is disposed at equal intervals around the periphery, as best shown in Figure 3. The movement of the drill collar relative to the wall contact assembly is achieved by applying different pressures, in a controlled manner, to each of the four actuators 44.

The form of the actuators could be a flexible hose or tube 44 or a variation thereof, with one end blanked off and the other end connected to a hydraulic supply and return pipe. The flexible material could be woven polyester or nylon coated with a suitable elastomer such as Viton (Registered Trade Mark).

Four of these tubes 44 are fitted into the annular space 46 reserved for the actuators, as shown in Figure 3. In the neutral position the cross section of each tube 44 would be partially flattened. As hydraulic fluid is supplied to any one actuator it has the tendency to return to its circular cross section and hence a radial force is applied at the actuator location which is dependent on the

hydraulic fluid pressure and the cross sectional geometry of the actuator. Provided the actuator diametrically opposite to the actuator being filled is allowed to vent, the actuator bridge member 41 and hence the drill collar 10 will be moved radially with respect to the actuator housing. The use of four actuators allows the actuator bridge member 41 to be positioned at any location relative to the actuator housing only within the limits of maximum radial movement.

An alternative mode of operation of this form of the invention is with the wall contact assembly not rotating with the drill collar. In this case the forward joint 35 is located on the drill collar by means of a bearing assembly 45 and the bearings 37 are locked to provide a rigid connection. It may be useful to configure this form of the invention so that the modes of operation can be interchanged by means of simple adjustments. With the wall contact assembly not rotating it may be that the anti-rotation device is not required, this function being provided by the wall contact assembly itself.

Attention is drawn to the applicants' specification GB-A-2172325 which discloses similar subject matter.

CLAIMS

1. Apparatus for deflecting a rotatable drill collar used in rotary drilling, comprising actuating means which do not rotate with the collar and which are operative to apply a controlled lateral force or displacement to the drill collar in order to deflect the latter to control the direction of drilling, the actuating means and the control thereof being down hole.

2. Apparatus according to Claim 1, wherein the actuating means apply controlled forces to the drill collar in each of two orthogonal directions, so that a deflection of any magnitude and in any radial direction can be applied by the actuating means to the drill collar.

3. Drilling apparatus comprising a rotatable drill collar, a drill bit carried by the end of the drill collar, two spaced stabilisers which act to locate the drill collar within a bore hole being drilled, and down hole control means for controlling the drilling course, the control means comprising sensing means for sensing the actual drilling course, information storage means for storing a predetermined required drilling course, comparison means for comparing the sensed course with the required course and for delivering an error signal in dependence upon the comparison, and actuating means which do not rotate with the collar and which apply a controlled lateral force or displacement to the drill collar in order to deflect the latter between the spaced stabilisers to vary the drilling course in dependence upon said error signal.

4. Drilling apparatus according to Claim 3, wherein the sensing means sense direction and inclination of the bore hole course relative to the earth's magnetic and gravitational fields respectively.

5. Drilling apparatus according to Claim 3, wherein the actuating means include a control stabiliser which applies the controlled lateral force or displacement and which is located between said spaced stabilisers.

6. Drilling apparatus according to any of Claims 3 to 5, wherein the information storage means are provided with information which relates to the desired direction and inclination of the bore hole course, and also to the maximum desired curvature of the bore hole during the transition from the initial bore hole course to the desired bore hole course.

7. Drilling apparatus according to any of the preceding claims, wherein the actuating means comprise flexible tubes or bags which when supplied with hydraulic fluid expand until the required deflection of the drill collar is obtained.

8. Drilling apparatus according to Claim 7, wherein the required hydraulic fluid flow and pressures are generated by a reciprocating pump or pumps which are driven from the rotating drill collar.

9. Drilling apparatus according to Claim 8 as appendant to Claim 3, wherein control of the hydraulic fluid is exercised by valves which divert the fluid flow in accordance with control signals generated by the comparison means.

10. Drilling apparatus constructed and arranged substantially as herein particularly described with reference to the accompanying drawings.